

# Technology Roadmap July 2011 PhysPAG Technology SAG \* [Draft - 07/25/11]

## Decadal Survey 2010 (New Worlds New Horizons)

## Near Term Push Technologies \*\*

## Long Term Push Technologies \*\*

	WFIRST	LISA	IXO	Inflation Probe	Fundamental Physics	Advanced mm-wave/far-IR Arrays	Next Generation Hard X-ray Obs.	Soft X-ray and EUV	Next generation X-ray timing	Next generation Medium-energy γ-ray Observations	Beyond LISA (Big Bang Observer)		Beyond IXO (Gen-X)	Next generation γ-ray Focusing
<b>Science Summary</b>	Study the nature of dark energy via BAO, weak lensing and SNIa, IR survey, census of exoplanets via microlensing	Probe black hole astrophysics & gravity signatures from compact stars, binaries, and supermassive black holes	Conditions of matter accreting onto black holes, extreme physics of neutron stars, chemical enrichment of the Universe	Study the Inflationary Epoch of the Universe by observing the CMB B-mode polarization signal	Precision measurements of space-time isotropy and gravitational effects	Enhanced sensitivity or reduced resources for the Inflation Probe; far-infrared astrophysics	Hard X-ray (5-600 keV) imaging all sky survey for BHs	Spectroscopy of million degree plasmas in sources and ISM to study composition	EOS of neutron stars, black hole oscillations, and other physics in extreme environments	Signatures of nucleosynthesis in SNR, transients, and other sources; AGN and black hole spectra	To directly observe gravitational waves resulting from quantum fluctuations during the inflation of the universe		Observe the first SMBH, study growth and evolution of SMBHs, study matter at extreme conditions	Signatures of nucleosynthesis in SNR, transients, and other sources
<b>Architecture</b>	Single 1.5 M dia. Telescope, with focal plane tiled with HgCdTe (TBD).	Three space craft constellation, each in Keplerian orbit. Sub arcsecond placement measured by lasers (Michelson interferometer).	Single 2.5 - 3 M grazing incidence 20 m focal length X-ray telescope	High-throughput cooled mm-wave meter class telescope with large-format polarization-sensitive detector arrays	Individual spacecraft for space-time measurement and gravitational effects. Multiple spacecraft for precision timing of interferometric measurements.	High-sensitivity, large-format, multi-color focal planes for mm-wave to far-infrared imaging, polarimetry & spectroscopy	Two wide-field (~130 x ~65deg) coded mask telescopes. Full sky ca. ~95min	Focusing optics with high resolution spectrometers based on advanced gratings	large(>3m <sup>2</sup> ) pointed arrays of solid state devices, with collimation to isolate sources	Single platform designs to measure γ-ray lines	Four Michelson interferometers each of three s/c (~12 s/c total), ~50,000 km separation, LISA like	Constellation of at least 2 cold atom differential accelerometers, 10,000 km measurement baseline	16 M (50 M <sup>2</sup> grazing incidence telescope with 60 M focal length	2-platform designs to measure γ-ray lines
<b>Wavelength</b>	0.4 to 1.7 μm (TBD)	Interferometer λ= 1.064 μm - gravity wave period 10-10,000 sec.	0.3 to 40 keV	1 - 10 mm		30 μm - 10 mm	5-30 and 10-600keV	5-500 Angstroms	2-80 keV	100 keV - 30 MeV	visible & near IR: gravity waves periods of ~1-10 sec	gravity wave periods 0.01 - 10 Hz	0.1-10 keV	100 keV-3 MeV
<b>Telescopes and Optical Elements</b>	Wide FOV, ~1.5-M diameter mirror	Classical optical design Surface roughness < λ/30, backscatter/ stray light	lightweight, replicated x-ray optics.	High-throughput, light, low-cost, cold mm-wave telescope operating at low backgrounds; Anti-reflection coatings; Polarization modulating optical elements			Coded aperture imaging: ~5mm thk W & ~2.5mm holes; ~0.5mm W & ~0.2mm holes	Gratings, single and multilayer coatings, nano-laminate optics	No optics; source isolation by collimator	Compton telescope on single platform	~ three meter precision optics (f/1000)	~ one meter precision optics (f/1000)	Lightweight adjustable optics to achieve 0.1 arcsec. High resolution grating spectrometer	Focusing elements (e.g., Laue lens) on long boom or seapage platform
		Alignment sensing, Optical truss interferometer, Refocus mechanism			Coupling of ultra-stable lasers with high-finesse optical cavities for increased stability	Large throughput, cooled mm-wave to far-infrared telescope operating at background limit.		Actuators			LISA Heritage	wavefront sensing with cold atoms; large area atom optics	0.1 arcsec adjustable optic	
	Classic telescope structure - HST heritage	Athermal design with a Temp gradient Dimensional stability: pm/sqrt(Hz) and um lifetime, angular stability < 8mrad	lightweight precision structure				~ 5° spec req. over ~6x-3x-1.5m tel. structures	Arcsecond attitude control to maintain resolution	Moderate accuracy pointing of very large planar array		LISA Heritage	10 W near IR, narrow line	Extendable optical bench to achieve 60 M focal length	Long booms or formation flying
<b>Detectors &amp; Electronics</b>	HgCdTe CMOS (H4RG?)	Laser: 10yr life, 2W, low noise, fast frequency and power actuators Quadrant detector, low noise, 10yr life, low noise (amplitude and timing) ADC's	X-ray calorimeter central array (~1,000 pixels); 2.5 eV FWHM @ 6 keV, extended array; 10 eV FWHM @ 6 keV. High rate Si detector (APS). High resolution gratings (transmission or reflection)	Large format (1,000 - 10,000 pixels) arrays of CMB polarimeters with noise below the CMB photon noise and excellent control of systematics	Molecular clocks/cavities with 10E-15 precision over orbital period; 10E-17 precision over 1-2 year experiment. Cooled atomic clocks with 10E-18 to 10E-19 precision over 1-2 year experiment.	Very large format (> 10 <sup>8</sup> pixels) focal plane arrays with background-limited performance and multi-color capability	1m <sup>2</sup> Si (~0.2mm strips)~6m <sup>2</sup> CZT (~1.2mm pixels); ASIC on ca. ~20x20mm crystal, photon-counting over cont. scan	Photocathodes, micro-channel plates, crossed-grid anodes	>3 m <sup>2</sup> Si (or CZT or CdTe) pixel arrays or hybrid pixels, with low-power ASIC readouts, possibly deployable	Cooled Ge: arrays of Si, CZT or CdTe pixels and ASIC readouts	Laser interferometer, ~1kWatt laser, gravity reference unit (GRU) with ~100x lower noise	Megapixel col camera	Gigapixel X-ray active pixel sensors, megapixel microcalorimeter array	Scintillators, cooled Ge
<b>Coolers &amp; Thermal Control</b>	Passively cooled telescope, actively cooled focalplane?	Low CTE materials, passive thermal shielding, power management for avionics thermal stability	Cryocooler needed to cool detectors and other parts of instruments	Passive Spitzer design plus cooling to 100 mK	Thermal stability/control, less than 10E-8 K variation.	Cooling to 50 - 300 mK	LHP to radiators for ~30deg (Si) and ~-5deg (CZT) over large areas		Passive cooling of pixel arrays	Active cooling of germanium detectors	LISA Heritage	Sun-shield for atom cloud	Cryocooler <100mK with 1 mK stability (IXO Heritage)	Active cooling of germanium detectors
<b>Distributed Space Craft</b>		Spacecraft in separate Keplerian orbits. No formation flying or station-keeping. Low contamination μ-Newton thrusters with low thrust noise			Applicable as precision timing standard in distributed constellations.			Use low-cost launch vehicles for single payloads with few month mission duration			~12 s/c total ~50,000 km separation, sub-micron position control.	Multi-platform s/c system to support above architecture		2-platform formation flying is one approach

\* Derived and updated from 2005 Strategic Roadmap-8 and Universe Roadmap

\*\* Emerging technologies needed for applications in next decade (near-term push) and beyond (long-term push)

TRL7-9

TRL 4-6

TRL 1-3